SUBMITTED TO *The Astrophysical Journal* JULY 23, 2003
Preprint typeset using LATEX style emulateapj v. 9/08/03

A FLUX LIMITED ATLAS OF GALAXY CLUSTER TEMPERATURE MAPS

R. HANK DONNELLY, C. JONES, W. FORMAN, E. CHURAZOV, M. GILFANOV
Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA.
e-mail: rdonnelly@cfa.harvard.edu
submitted to The Astrophysical Journal *July 23, 2003*

ABSTRACT

An atlas of gas temperature maps is presented for a flux limited catalog of galaxy clusters. The sample of clusters is based on the Edge et al. (1990) sample, with the inclusion of five additional clusters, all with fluxes $f_X(2-10\text{ keV}) \geq 1.7 \times 10^{-11}$ ergs sec^{-1} cm^{-2}, drawn from a variety of other sources. The temperature maps are derived from *ASCA* GIS observations using a common methodology to correct for the Point-Spread Function and calculate the local projected gas temperature in such a way so as to make each cluster directly comparable to all others in the sample. Variations in the temperature distribution, when present at $> 90\%$ confidence, are characterized by their severity and extent. We find that 70% of the clusters in our sample have significant variations in the projected gas temperature. The presence of these variations increases with increasing luminosity, as does the spatial scope and severity within a cluster. For a more limited sample we find that one third of clusters with temperature structure have radio halos. The high rate of occurance of structure emphasizes the need for caution when using clusters to measure cosmological parameters.

Subject headings: atlases — galaxies: clusters: general — galaxies:ICM — X-rays: galaxies : clusters

1. INTRODUCTION

The hot intracluster medium (ICM) is the dominant component of the luminous baryons in galaxy clusters. This diffuse gas, typically heated to tens of millions of degrees Kelvin, comprises about 25% of the total mass and approximately five times the mass in the galaxies (Blumenthal et al. 1984; David et al. 1990; Arnaud et al. 1992; White et al. 1993; David, Jones & Forman 1995; White & Fabian 1995; Allen et al. 2003). Multiple studies of the X-ray surface brightness of the ICM (Abramopoulous & Ku 1983; Jones & Forman 1984; Fabricant et al. 1986; Edge & Stewart 1991a, 1991b; Mohr, Fabricant & Geller 1993; Slezak, Durret & Gerbal 1994; Durret et al. 1994; Buote & Xu 1997; Jones & Forman 1999) have shown that a substantial percentage (40%) of clusters are dynamically active and have observationally confirmed the suggestion that "the present is the epoch of cluster formation" (Gunn & Gott 1972).

However, characterizing the dynamical state of a cluster by this approach is limited somewhat by the viewing geometry and the relatively rapid return of the surface brightness to a relaxed distribution (Schindler & Müller 1993; Ricker 1998). In contrast, variations in the projected gas temperature due to merger events can persist for longer timescales and are detectable even when the merger is along the line of sight. Thus with the advent of spatially resolved spectroscopic instruments (e.g. *ASCA*, and more recently *CHANDRA* and *XMM-Newton*), we are more sensitive to detecting merger events and are able to test the nominal assumption of isothermality (see e.g. Markevitch et al. 1998). Deviations from this assumption have important consequences for determinations of cluster masses, and thence to the determination of the fractional amount of matter contained in gravitationally bound systems as well as for testing cosmological models (Reiprich & Böhringer 2002).

In this paper we present an atlas of the gas temperature distributions for 58 galaxy clusters comprising a flux limited sample. By analyzing this sample using a common set of techniques and levels of confidence we can make direct comparisons between the various members and explore the presence of substructure at the current epoch. Our sample also highlights potential complications for higher redshift objects and can be used as a comparison sample for simulations testing cosmological parameters.

Section 2 describes the development of our sample; Section 3 outlines the issues involved in the derivation of robust gas temperature maps from *ASCA* observations, and describes in general the methodology applied. Section 4 details the global results for each cluster and presents the gas temperature maps for each cluster sorted by decreasing luminosity. Section 5 describes correlations of the temperature structure with luminosity and the presence of radio halos. We have applied the WMAP cosmology (Bennett et al. 2003)– $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$ and $H_0 = 71$ km sec^{-1} Mpc^{-1}– to derive all distance related quantities.

2. THE SAMPLE

Our sample uses the flux limited catalog of Edge et al. (1990; revised in 1992) as its foundation. These 55 clusters from the *EINSTEIN*, *HEAO-1*, and *EXOSAT* data sets have 2-10 keV fluxes greater than 1.70×10^{-11} ergs cm^{-2} s^{-1}. By reviewing other catalogs of clusters (David et al. 1993, hereafter D93; Ebeling et al. 1998; DeGrandi et al. 1999; Jones & Forman 1999) we have augmented this list with five additional clusters that meet the flux limit requirements: A1835, A2163, A3395, A3627 and Z5029. A3395 was originally included in the sample (Edge et al. 1990), but was replaced by A3391 in the revision (Edge, Stewart & Fabian 1992). Our sample includes both clusters. Following the detailed treatment of the completeness in Edge et al. (1990), we estimate that our augmented sample is 80-100%

complete (60 of 60-75 clusters), with the Log N-Log S and $\langle V/V_{max}\rangle$ distribution estimates giving approximately 98% completeness (60 of 61 clusters). We note that only one of our additions to the sample (A3627) is located at low galactic latitudes ($|b| < 20°$). For all but two of the sixty clusters (A1644 and Z5029), pointed observations using the *ASCA* GIS were available, and it is these data which we then used to generate our gas temperature maps.

3. GENERATING THE TEMPERATURE MAPS

Spatially resolved spectroscopy is strongly dependent on the Point-Spread-Function (PSF) in two ways. First is the loss of sensitivity and angular resolution due to the scattering by the telescope of photons from their nominal true locations. This limits the pixel to pixel contrast that can be reliably extracted from the data. This is well known and understood for the photon intensity, but applies equally well to spectral information. The second effect occurs when the PSF has a strong dependence upon energy, as was the case with the *ASCA* satellite (Takahashi et al. 1995). This leads to a spatially dependent distortion of the derived spectra. In the case of a centrally concentrated extended source, such as a cluster of galaxies, this can lead to spurious gradients in the derived temperature and abundance distributions of the hot intracluster gas, such that the outer regions will appear hotter with higher abundances than actually present. The amplitude of this aliasing increases with temperature and decreases with the angular size of the cluster. This makes correction of the PSF of paramount importance for producing reliable maps of the temperature distribution.

As a first step in the analysis, the *ASCA* data were "cleaned" with standard processing tools (Arnaud 1993). A cutoff rigidity of 8 GeV/c, minimum Earth elevation angles of 5°, and a maximum count rate of 50 cts/s in the radiation belt monitor were used. The GIS background was generated from an appropriately weighted combination of background maps for all rigidities.

We then applied a technique developed by Churazov et al. (1996, 1999) to correct the PSF and calculate the projected gas temperature distribution. This method relies on the existence of a compact core in the *ASCA* PSF, and the assumption that the total PSF can be represented as the sum of two components: a core PSF and an extended "wings" PSF. The components are defined such that the wings contain only a small fraction of the total photons detected and the core is relatively small ($r < 6'$) in extent. Then a direct correction of the core PSF is combined with a Monte-Carlo simulation of the effects of the wing component to produce the overall energy dependent PSF. The simplicity of this method makes its implementation computationally fast, and it can be performed in each of the 1024 *ASCA* GIS energy channels on a fine ($\approx 15''$) angular grid.

After correction for the PSF, the shape of the spectrum at a given position is characterized as a linear combination of two template spectra. The two template spectra correspond to optically thin plasma emission models at two different temperatures chosen so as to widely bracket the nominal overall temperature of the cluster. These are generated using a MEKAL model from XSPEC, convolved with the efficiency of the telescope and the GIS detector.

The two template spectra, although their heavy element abundances were universally set to 0.3 solar, were individually tailored for each cluster, by fixing the absorption column density to the appropriate Galactic value and setting the redshift to the value found from NED. We then attempted to generate a temperature map. If the template spectra did not provide good bracketing for the cluster temperature, we iterated until appropriate values for the templates were found.

The best fit weights of these template spectra needed to describe the spectrum $S(E)$ observed in a given $15''$ pixel of the image are then determined, i.e.

$$S(E) = A \cdot M(T_1, E) + B \cdot M(T_2, E), \tag{1}$$

where $M(T, E)$ is the template spectrum for a given value of temperature T, and the temperature is then calculated as a function of the relative weights of the template spectra. Due to the linear nature of the method, no complex fitting is required and, hence, the method is computationally fast. Although the limitations of this method are significant (e.g., simple spectral forms must be assumed *a priori*), this combined approach allows for reliable and rapid generation of temperature maps specifically with the intent of examining two dimensional spatial variations in gas temperature.

Churazov et al. (1996) have shown that an expectation value of the temperature calculated this way is accurate (within a few percent of the temperature obtained by conventional spectral fitting e.g. XSPEC) under the assumption of a single temperature plasma with fixed metallicity and absorption. This approach also has been previously compared to other methodologies (Markevitch 1996a; Markevitch et al. 1998, hereafter M98) and found to yield consistent results (A1367- Donnelly et al. 1998; Coma- Donnelly et al. 1999).

Finally in generating the temperature maps, an adaptive smoothing has been applied in order to reduce the noise throughout the image. The parameters of the adaptive smoothing have been adjusted so as to produce comparable levels of uncertainty (~ 0.7 keV at roughly the 90% confidence) across the entire range of temperatures and intensities in our sample. As a last step, the intensity contours from the *ASCA* data are overlaid on the temperature maps.

4. RESULTS AND ANALYSIS

Details of each observation as well as other "global" parameters for each cluster are given in Table 1. The columns in the table are as follows:

- *Column 1* gives the most common name for each cluster; other common aliases for especially well known clusters (e.g. Coma) are also listed here, while less common aliases are given in the notes section.
- *Columns 2 and 3* give the J2000 Right Ascension and Declination as determined from centroiding the X-ray emission detected by the *ASCA* GIS.

- *Column 4* is the redshift from the NED database.
- *Columns 5 and 6* give the *ASCA* sequence number(s) and observation length(s).
- *Column 7* gives the weighted value of the neutral hydrogen column density within a 0.5° cone centered on the cluster emission from the FTOOL *nh*, in units of 10^{20} cm^{-2}.
- *Column 8* is a global emission weighted temperature with a 90% confidence error bar. This was found by fitting all of the *ASCA* data within either a 1 Mpc or $20'$– whichever was smaller– radius aperture centered on the X-ray emission with a single Raymond-Smith model. Point sources were not excluded, similar to the treatment in M98. Because there were no *ASCA* observations of A1644 and Z5029, the result for A1644 is the *EINSTEIN* MPC result taken from D93 and that for Z5029 is taken from Ebeling et al. (1998).
- *Column 9* is the unabsorbed flux in the energy range from 2-10 keV within an aperture of $45'$ diameter in units of 10^{-11} $ergs\ sec^{-1}\ cm^{-2}$. The data, except for three clusters, were measured by the *EINSTEIN* MPC and reported in D93 or Edge et al. (1992) catalogs. For the the other three clusters (Z5029, A1835 and A3627) estimates of their fluxes were derived from *ROSAT* PSPC data and then converted to the MPC energy band (2-10 keV) using PIMMS.
- *Column 10* is the 2-10 keV X-ray luminosity, in 10^{44} ergs sec^{-1}, found from applying the WMAP cosmology (Bennett et al. 2003)– $\Omega_m = 0.27$, $\Omega_\Lambda = 0.73$ and $H_0 = 71$ km sec^{-1} Mpc^{-1}.
- *Column 11* gives our structural index discussed below in the text. If we found a variation in the gas temperature at the ≥90% confidence level, the first component (1,2,3) gives the severity of the temperature change, while the second component (S,L) gives the spatial extent of the variation.
- *Column 12* lists the rank of this cluster by luminosity and is to aid in locating the cluster in the collection of luminosity ordered temperature maps (Figure 2).

When a significant (≥90% confidence) variation in the gas temperature was detected in a cluster, we characterized the variation based upon severity and extent. Each of these two metrics was assessed independently, and they are listed in the Structural Index column of Table 1. The first component (‘1,2, or 3’) gives the severity of the temperature change: ‘1’ is mild ($2.4 < \Delta T < 4.3$ keV), ‘2’ is strong ($4.2 < \Delta T < 5.8$ keV), and ‘3’ is extreme ($\Delta T > 5.8$ keV). The second component (‘S,L’) gives the spatial extent of the temperature changes over the cluster, where ‘S’ indicates a small, localized variation (less than one quadrant of the temperature map), while ‘L’ notes a variation that extends over more than one quadrant.

A comparison between our overall temperatures and those from D93 and M98 is given in Figure 1. We find that our results are in good agreement with the 55 *EINSTEIN* MPC results of D93. The comparison to the thirty clusters from the M98 sample is even better. For our three hottest clusters (A754, A2163 and Triangulum Australis), we have plotted results from sources other than M98. The temperature for A754 derives from a recent *CHANDRA* result (Markevitch et al. 2003), that for Triangulum Australis from earlier work (Markevitch 1996a) and for A2163 from Holzapfel et al. (1997). While four clusters (A401, A2029, A3571 and A3266, all discussed in the Section 4.2) lie off the 1:1 line in the comparison with the M98 sample, the correlation between the two sets of temperatures, derived from the same *ASCA* data, but using very different methodologies, is very tight. We have also explored whether there is any systematic effect due to our decreased aperture for higher redshift ($z > 0.042$) clusters and find no such effect.

4.1. *The Temperature Maps*

The maps of the gas temperature distribution for the entire flux limited *ASCA* sample are presented in Figure 2. They are ordered by decreasing X-ray luminosity (in the energy range from 2-10 keV) and all, except the very hot clusters A2163, A2319, Ophiucus, and A754, have a common color scale for ease of comparison. For these four the scale was shifted to accommodate their peak temperatures. Although both the lower and upper limiting values for the temperature range for these four clusters differ from the rest of the sample, the stretch of the scale is the same for the entire sample. To highlight that these four scales are different, the location and orientation of the scale bar was changed to lie along the vertical axis, rather than the horizontal axis, as for all the others.

The stretch of the scale was chosen such that one “band” of color is approximately equivalent to the local uncertainty in the temperature determination. This means that the presence of *four* colors indicates a significant (greater than 90% confidence) change in the temperature.

4.2. *Notes for individual clusters*

What follows are comments for individual clusters– aliases, significant changes in the global temperature, conversion of the aperture radius to Mpc for nearby clusters ($z < 0.042$) where the global temperature was aperture limited, etc. We have searched the literature using the article links built into the *XMM-Newton* Science Archive and *CHANDRA*’s WebChaSeR to compare our results to the most recent, high resolution results. Within our sample of sixty clusters, we have found cluster gas temperature results based upon *CHANDRA* data for twenty-seven. Six of these also have results published using *XMM-Newton* data, while a seventh (Coma) has *XMM-Newton* results, but none from *CHANDRA*.

Although, the results are often difficult to compare, due to the much higher angular resolution and the different fields of view, especially for *CHANDRA*, we comment below upon the qualitative comparisons between the *ASCA* and *CHANDRA*/*XMM-Newton* data sets. We note that of this set of twenty-seven observed at higher resolution, only seven (Perseus, A3266, A754, A1367, Virgo, Coma and A2256) cover spatial extents comparable to our maps.

We also compare our results with previous work derived from *ASCA* data but using different methodologies. Of the twenty-seven with *CHANDRA* results, eleven had previous results (other than ours) from *ASCA*, while another twelve clusters with previous *ASCA* measurements have no published *CHANDRA* or *XMM-Newton* analyses. Temperature maps for the remaining eighteen clusters appear here for the first time.

- *A85:* Kempner, Sarazin & Ricker (2002) have studied the $6' \times 6'$ region surrounding the "southern sub-cluster" using *CHANDRA* data. Our temperatures and the sense of the gradients on the two sides of the subcluster are in good agreement with these results. Our results are also in good agreement with previous *ASCA* results reported by M98. The *XMM-Newton* results of Durret et al. (2003) deal with the extended filamentary emission outside our field of view.

- *A119:* Our results are in good agreement with previous *ASCA* results derived using a different methodology (M98).

- *A262:* The global fit temperature was restricted to a $20'$ (0.39 Mpc) radius.

- *AWM 7:* The global fit temperature was restricted to a $20'$ (0.41 Mpc) radius. This cluster is also known as WBL 88.

- *A399:* Our results are in excellent agreement with previous *ASCA* results (M98).

- *A401:* Except in one region– our results are in excellent agreement with previous *ASCA* results (M98). A hot feature indicated in our map lies in region 9 from M98.

- *A426/Perseus:* The global fit temperature was restricted to a $20'$ (0.43 Mpc) radius. This cluster is centered on NGC 1275. Our results are consistent with both the high (inner $5'$) and moderate (inner $9'$) resolution maps of the gas temperature generated by Schmidt, Fabian & Sanders (2002) with *CHANDRA* data. Our results are also in excellent agreement with the *XMM-Newton* map of the gas temperatures across the entire cluster (Churazov et al. 2003).

- *2A0335+96:* The global fit temperature was restricted to a $20'$ (0.82 Mpc) radius. This cluster is also known as RXJ0338.6+0958.

- *A478:* The azimuthally averaged radial temperature profile to $r = 6'$ from Sun et al. (2003) using *CHANDRA* data is consistent with the inner region of our map.

- *A3266:* This cluster is also known as Sersic 40/06. Our map, previously reported in Henriksen, Donnelly & Davis (2000), is consistent across the entire cluster with the *CHANDRA* data presented by Henriksen & Tittley (2002). Our results are also in agreement with previous *ASCA* results (M98). We note that although the 2D maps of the temperature distribution are in agreement with that of M98, the overall temperature given by M98 is significantly lower than ours (7.7 ± 0.8 keV versus 9.3 ± 0.4 keV; see Figure 1).

- *A496:* The global fit temperature was restricted to a $20'$ (0.78 Mpc) radius. Our results are consistent both with the *CHANDRA* results (the inner $4'$) from Dupke & White (2003) as well as those from Tamura et al. (2001b) within a radius of $9'$ from *XMM-Newton.* Our results are also in agreement with previous *ASCA* results (Markevitch et al. 1999b).

- *3C129.1:* The global fit temperature was restricted to a $20'$ (0.53 Mpc) radius. Our results are consistent with the radial temperature profile (out to $19'$) derived from the *CHANDRA* data by Krawczynski (2002).

- *A3391:* Our results are consistent with previous *ASCA* results (M98).

- *A3395:* This cluster is also known as SC0627-54. Our results were previously reported in Donnelly et al. (2001). Our results are also in good agreement with previous *ASCA* results (M98).

- *A576:* The global fit temperature was restricted to a $20'$ (0.91 Mpc) radius.

- *PKS0745-19:* We note the large change in the fit global temperature from $8.5^{+1.9}_{-1.4}$ keV (D93) to $6.4^{+0.1}_{-0.2}$ keV. Our results are consistent with the radial temperature profile and a 2D temperature map of the inner $1.6' \times 1.6'$ using *CHANDRA* data (Hicks et al. 2002).

- *A644:* Our results are generally consistent out to $10'$ with previously reported *ASCA* data (Bauer & Sarazin 2000). We note that their region 5 is cooler than what we find for this area, while their region 3 is hotter than our results.

- *A754:* Our results are consistent across the entire cluster with the *CHANDRA* results from Markevitch et al. (2003). We also note that we are consistent with previous results from the same *ASCA* data, but using a different methodology for correcting for the PSF and generating the temperature maps (Henriksen & Markevitch 1996). For the comparison to our overall temperature in Figure 1, we have used the *CHANDRA* result from Markevitch et al. 2003 (10.0 ± 0.3 keV) which is inconsistent at the 90% confidence level with that found in M98 (9.0 ± 0.5 keV).

- *Hydra A:* Our results are in good agreement with *CHANDRA* results for the inner $5'$ radius (Nulsen et al. 2002; David et al. 2001; McNamara et al. 2000).

- *A1060:* The global fit temperature was restricted to a $20'$ (0.31 Mpc) radius. This cluster is also known as Hydra. Our results are consistent with the high resolution *CHANDRA* map generated for the inner $1.5'$ by Yamasaki, Ohashi & Furusho (2002).

- *A1367:* The global fit temperature was restricted to a $20'$ (0.53 Mpc) radius. Our results, previously reported in Donnelly et al. (1998), are in excellent agreement across the entire cluster with the *CHANDRA* temperature map (Sun & Murray 2002b).

- *Z5029:* This cluster is also known as ZwCl1215.1+0400.

- *Virgo:* Due to the extreme proximity of this cluster (16 Mpc) the data is restricted to only the core of the cluster emission around M87. The global fit temperature was restricted to a $20'$ (0.088 Mpc) radius. Our results are in very good agreement with data from both *CHANDRA* and *XMM-Newton* for the inner $16' \times 16'$ (DiMatteo et al. 2003; Molendi 2001; Gastadello & Molendi 2002; Böhringer et al. 2001).

- *A3526/Centaurus:* The global fit temperature was restricted to a $20'$ (0.28 Mpc) radius. This cluster is also known as Klemola 20. Our results are consistent with those found for the inner $4'$ by Sanders & Fabian (2002) with *CHANDRA* data. A similar map of the gas temperatures, developed with an earlier version of our software, appears in Churazov et al. (1999).

- *A3532:* This cluster is also known as Klemola 22.

- *A1651:* We find very good agreement with previous *ASCA* results (M98).

- *A1656/Coma:* The global fit temperature was restricted to a $20'$ (0.55 Mpc) radius. Our results, previously reported in Donnelly et al. (1999), are in good agreement with recent *XMM-Newton* results (Neumann et al. 2003) including the region of hot gas located to the north of the two central galaxies. We note that early *XMM-Newton* results using just the EPIC/MOS detectors (Arnaud et al. 2001a), although in good general agreement elsewhere, did not find the hot region north of the central galaxies. At the same time, data using the EPIC/pn detectors (Briel et al. 2001) did find very small scale, hot features which they suggested might be the source of the 'hot spot' that we find in the *ASCA* data.

- *A1689:* Our results are in good agreement with the *CHANDRA* radial temperature profile for the inner $3'$ (Xue & Wu 2002).

- *A3558:* This cluster is also known as Shapley 8. We note that the global temperature reported in D93 is significantly lower than our result (3.8 ± 2.0 keV versus $5.8^{+0.3}_{-0.2}$ keV). Our results are excellent agreement with previous *ASCA* results (Markevitch & Vikhlinin 1997a).

- *A3571:* The global fit temperature was restricted to a $20'$ (0.92 Mpc) radius. Our 2D results are in excellent agreement with those derived from *ASCA* by M98. For the global temperature, our aperture is significantly larger ($20'$ versus $16'$) than that used to derive the M98 mean temperature. The offset in temperature (larger aperture, higher temperature) is similar to that found for A2029 (Figure 1).

- *A1795:* Our results are consistent with both the *CHANDRA* (Ettori et al. 2002; Markevitch, Vikhlinin & Mazzotta 2001a) and *XMM-Newton* (Arnaud et al. 2001b; Tamura et al. 2001a) radial temperature profiles out to $4'$ and $12'$ respectively.

- *A1835:* Our results are in good agreement with the *XMM-Newton* radial profiles of the temperature to a radius of $7'$ (Majerowicz, Neumann & Reiprich 2002; Peterson et al. 2001). At the largest radius ($r = 3.3'$), the *CHANDRA* temperatures are higher than ours (10-16 keV versus 7-8.5 keV) (Schmidt, Allen & Fabian 2001), although Markevitch (2002a) indicates that this disagreement is due to background flaring in the *CHANDRA* data.

- *A2029:* Our results are consistent with the *CHANDRA* azimuthally averaged radial temperature profile out to $4'$ (Lewis, Buote & Stocke 2003; Lewis, Stocke & Buote 2002). We are also in broad agreement with the low resolution azimuthal profile found with *ASCA* data using a different methodology (Sarazin, Wise & Markevitch 1998); we note that in our map the region of hot gas (Figure 2, panel 1, second row, far right) to the northwest

coincides with their very hot annular wedge. For the global temperature our aperture is significantly smaller (11′ versus 16′) than that used to derive the M98 temperature. The offset in temperature (larger aperture, higher temperature) is similar to that found for A3571 (Figure 1).

- *A2052:* The global fit temperature was restricted to a 20′ (0.83 Mpc) radius. Our results are consistent with the azimuthally averaged radial profile from *CHANDRA* and, although we can not resolve the cool feature in the inner 1.25′×1.25′, we are in general agreement with the 2D distribution of temperatures within this region (Blanton et al. 2001; Blanton, Sarazin & McNamara 2003).
- *MKW 3s:* This cluster is also known as WBL 564. Our results are in good agreement with the *CHANDRA* and *XMM-Newton* radial profile ($r < 10'$) and 2D map in the inner 4′×4′ (Mazzotta et al., 2002a).
- *A2065:* The global temperature value reported by D93 is significantly higher than our derived value ($8.4^{+3.3}_{-1.8}$ keV versus 5.8 ± 0.2 keV). Our results are in excellent agreement with previous *ASCA* results (Markevitch, Sarazin & Vikhlinin 1999a).
- *A2063:* We note that the value reported by D93 is significantly higher than our result ($4.1^{+1.2}_{-0.8}$ keV versus $2.6^{+0.2}_{-0.1}$ keV). The global fit was restricted to a 20′ (0.83 Mpc) radius.
- *A2142:* Our results are in good agreement in the inner 3′×3′ map from the *CHANDRA* data (Markevitch et al. 2000). Although we do not resolve the cold front features, we do find increasing temperatures at larger radii both to the west and east.
- *A2147:* The global fit temperature was restricted to a 20′ (0.83 Mpc) radius.
- *A3627:* This cluster is also known as the Norma Cluster. The global fit temperature was restricted to a 20′ (0.38 Mpc) radius.
- *A2163:* Our results are consistent with the 2D *CHANDRA* temperature map of the inner 6′×6′ (Markevitch & Vikhlinin 2001b), although we do not resolve the small cool features to the south and the detailed distribution of very hot gas to the east. We are also in agreement with previous *ASCA* results (Markevitch 1996a). We have included an overall temperature for this cluster (11.2 ± 1.1 keV from Holzapfel et al. 1997) in our comparisons with the results from M98 (Figure 1). This result was derived from *ASCA* data but not included in the M98 data set.
- *A2199:* The global fit was restricted to a 20′ (0.71 Mpc) radius. Although we do not resolve the cold region found in the *CHANDRA* 2D map of the inner 3′×3′ (Johnstone et al. 2002), our results are consistent with the overall map as well as the azimuthally averaged radial temperature profile. Our results are consistent with those reported previously using *ASCA* data (Markevitch et al. 1999b).
- *Triangulum Australis:* Our result for the global temperature is significantly higher than that reported in D93 (10.7 ± 0.5 keV versus 8.0 ± 1.4 keV), and is consistent with the result from Markevitch et al. (1996b) of 10.3 ± 0.8 keV. We note that this temperature is higher than the value (9.5 ± 0.7 keV) reported in M98.
- *A2256:* Our results are in excellent agreement with the *CHANDRA* results spanning the entire cluster (16′×16′) from Sun et al. (2002a). This includes the detection of hot gas to the south and southeast and cool gas to the west. Our results are also generally consistent with those previously reported in Markevitch (1996a) and Markevitch & Vikhlinin (1997b) using *ASCA* data.
- *Ophiucus:* The global fit temperature was restricted to a 20′ (0.67 Mpc) radius. Our *ASCA* results are significantly higher than those reported in D93 ($12.1^{+0.6}_{-0.4}$ keV versus $9.0^{+0.8}_{-0.7}$ keV). Our results are in excellent agreement with previous results derived from *ASCA* data using a different methodology (Watanabe et al. 2001).
- *2319:* Our results are generally consistent with those reported previously using *ASCA* data (Markevitch 1996a).
- *Cygnus A:* Due to the extreme brightness of the AGN within the field of view, we determined the overall temperature by performing a two component fit (Raymond-Smith and Power Law) to the spectrum after excluding emission from the AGN to a radius of 5′. This gives a temperature of 4.5 ± 0.7 keV which is consistent with the D93 value of $4.1^{+4.3}_{-1.3}$ keV. Comparison of our 2D map with other results is hampered for this one cluster due to the adaptive smoothing we have applied which increases the footprint of the bright point source. Away from the region surrounding the AGN, the agreement is very good with both *ASCA* and *CHANDRA* (Markevitch et al. 1999a and Smith et al. 2002 respectively)
- *A3667:* Although we do not resolve the sharp change in temperature , our results are in good agreement with the *CHANDRA* results for the inner 16′×16′ (Mazzotta, Fusco-Femiano & Vikhlinin 2002b; Vikhlinin, Markevitch & Murray 2001). Our results are in excellent agreement with previous *ASCA* results (Markevitch et al. 1999a).

- *A2597:* Our results are in good agreement with the azimuthally averaged radial temperature profile out to $3'$ generated by McNamara et al. (2001) using *CHANDRA* data.
- *A4038:* The global fit was restricted to a $20'$ (0.71 Mpc) radius. This cluster is also known as Klemola 44.
- *A4059:* Our results are in agreement with the general findings of the hardness ratio map for the inner $6'\times6'$ generated from *CHANDRA* data by Heinz et al. (2002). Our results are also in agreement with previous *ASCA* results (M98).

Ten of our clusters (AWM7, Perseus, 3C129, PKS0745, A644, A3627, Triangulum Australis, Ophiucus, A2319 and Cygnus A) lie at low galactic latitudes ($|b| < 20°$). It is possible that variations in our temperature maps may be due to very localized, but strong, variations in the Galactic hydrogen column density. To test this hypothesis, we examined in detail the derived values for the two low latitude clusters that had the most extreme temperature variations: A2319 and Ophiucus. We sampled the derived values of n_H at the maxima and minima of the temperature distributions. We find no systematic variations which would account for the temperature structures that we detect. We note that because the resolution of the Galactic n_H atlas' are very low (typically of order a degree) that the average weighted sampling available to us may not be sufficient to reveal structures in the Galactic hydrogen that would produce the features demonstrated by our temperature maps.

5. DISCUSSION

One of the most striking features of the maps of the gas temperature is the very high prevalence of structure. In our sample, 71% (41 of 58 clusters) show significant variations in gas temperature at the 90% confidence level. The leading model for large scale changes in the intracluster gas temperature is the dynamical interaction associated with two (or more) sub-cluster sized objects as they collide and eventually merge. Jones & Forman (1999) had previously found, based on isophotal maps from *EINSTEIN*, that at least 40% of clusters showed features suggesting large scale dynamical activity. Detecting structure from the X-ray surface brightness is limited by considerations of the geometry of the subcluster-cluster interaction. In contrast, gas temperature maps are not so constrained and can provide a more complete inventory of cluster merging phenomena. As a consequence, there are several clusters (e.g. A1689, A644 etc.), whose surface brightness distributions show no evidence for ongoing merger activity, i.e. their intensity isophotes are azimuthally symmetric. However, the temperature maps for these clusters do show significant structure, indicating recent dynamical activity.

We note that our estimates of the presence and severity of structure in the temperature distribution are very conservative. This is especially true for clusters with lower global temperatures. For example a cool cluster (~ 2 keV) with perturbed regions (~ 4 keV) would not meet the significance criteria derived from our adaptive smoothing for a 'significant' variation in temperature, even though the change ($\frac{\Delta T}{T}$) is 100%. Further, the high resolution results from *CHANDRA* and *XMM-Newton* indicate that many features in the gas are present on small angular scales. The *ASCA* data, due to its much more limited angular resolution, cannot detect these features. As a consequence the overall fraction of structure that we find in our sample should be considered as a lower limit.

Another important aspect of our results is that the 2-dimensional nature of our maps is more sensitive to temperature variations than radial profiles. This is especially true for clusters with very localized variations in temperature ('S' clusters e.g. A2142, A2029, etc.) where fitting the temperature in annuli would tend to conceal the temperature variations.

5.1. *Correlation of Temperature Structures and Luminosity*

In Figure 3 we plot the percentage of each level of temperature variation within the luminosity quintiles corresponding to the panels in Figure 2. Each quintile has nearly the same number of clusters (the second and third have eleven each, while the others have twelve).

Figure 3 shows that as luminosity increases the percentage of clusters with significant temperature variations also increases. In fact the two most luminous quintiles have *no* clusters that do not exhibit significant variation in gas temperature. This has implications for cosmological studies of distant clusters. Since most X-ray flux limited distant cluster samples are necessarily dominated by luminous clusters, they are also very likely to be dynamically unsettled. This will affect a variety of measures including estimates of the mean temperatures and derived masses, unless the clusters are observed for sufficiently long times with high spatial resolution to allow the derivation of temperature maps.

Figure 3 also shows that the severity of the fluctuations in temperature correlates with luminosity. We find that there are no class 3 clusters at low luminosities and no class 0 clusters at high luminosities. From a qualitative point of view this is not necessarily surprising. More luminous clusters are intrinsically more massive and are also likely to be located at the nodal center of several large scale structure filaments. Both of these properties would increase the frequency and severity of mergers with sub-cluster sized objects as well as the possibility of an equal mass cluster-cluster event, similar to what we see in our sample.

In a similar vein we find that for the two most luminous quintiles where all of the clusters have temperature variations, 75% (9 of 12) of the temperature variations are widespread (our 'L' classification). In the third and fourth quintiles, where seven of the eleven clusters have temperature structures, the split is roughly 50-50 (III: four of seven, IV: three of seven are 'L' class clusters) between widespread ('L') and localized ('S') variations. For the lowest luminosity

quintile, where only three of the twelve clusters have variations, two clusters have widespread variations and one is localized. This suggests that the more massive clusters are more likely to have merger activity which encompasses the entire cluster, i.e. a merger of roughly equal sized masses, whereas less luminous clusters absorb smaller subclusters.

5.2. *Correlation of Temperature Structures and Diffuse Radio Sources*

Several authors (Giovannini, Tordi & Feretti 2000; Kempner & Sarazin 2001) have explored the connection between diffuse radio sources not associated with specific galaxies (a.k.a. halos and relics) with merger activity and the lack of a cooling flow structure in the cluster. We have compared our sample with the halo/relic catalogs drawn from the NVSS and WENSS surveys to explore correlations between our structural index based on temperature maps and the presence of these diffuse radio sources.

There are some limitations to the two radio catalogs that strongly reduce the overlap with our cluster sample. The NVSS sample is constrained to objects with declinations above $\delta = -40°$ and due to baseline considerations is insensitive to structures at redshifts less than $z = 0.042$. The WENSS sample, although able to detect sources as close as $z = 0.01$, only covers the sky northward of $\delta = 30°$. Applying these restrictions to our sample, there are 31 clusters which are included in both our flux limited X-ray sample and either the NVSS or the WENNS radio samples.

Of these 31 clusters, 24 exhibit some level of significant temperature structure. Only eight of the 31 (A85, A401, A754, A2142, A2163, A2256, A2255 and A2319) have some form of a radio halo/relic, and all of these exhibit temperature variations indicative of a merger. Two additional clusters from our X-ray sample (Coma and A3667, both with temperature structure) also have either a halo or relic, but are missed by the NVSS and WENSS surveys due to redshift and/or declination considerations. We have searched the literature for detections of other radio halos or relics and found no others that are also in our flux limited X-ray sample. This suggests that while the presence of a radio halo/relic indicates temperature variations in the gas, that the reverse is not necessarily true.

We then compared the presence of a radio halo/relic with our structural index, specifically the eight most thermally perturbed clusters (our class '2' and '3' clusters). While four clusters (A754, A2163, A2256 and A2319) have either a radio halo or relic, the other four clusters (A478, A2029, Cygnus A and A2244) do not. It is possible a halo/relic exists in Cygnus A, but that the brightness of the AGN located near the center of the cluster precludes detection of a diffuse source. At the next lower level of temperature variation, eleven class '1' clusters, which lie within the coverage of the NVSS sample, do not have either a radio halo or relic detected within them. However, the other six class '1' clusters (A85, A401, A2142 and A2255, as well as Coma and A3667) do have a radio halo/relic. This suggests that the presence of a radio halo/relic does not correlate with the severity of the variation in the gas temperature.

From this small sample, we find that one third of clusters with temperature variations (eight of twenty four) have either a radio halo or relic, and that the presence of a halo/relic does not correlate with severity of the temperature structure. Due to the suggested connection between cluster merging and radio halos/relics (Kempner & Sarazin 2001), this highlights the potentially interesting exceptional nature of those highly perturbed merging clusters that do not contain a halo/relic source (i.e. A478, A2029, Cygnus A and A2244).

6. SUMMARY

Maps of the gas temperature in galaxy clusters are a strong test for the presence of dynamical effects, particularly mergers. This is because they are not as dependent upon viewing geometry as the X-ray surface brightness and the temperature variations are erased on longer time scales than surface brightness variations (Schindler & Müller 1993; Ricker 1998). The flux limited atlas of galaxy cluster temperature maps presented here shows a rich diversity of structure across the entire sample, particularly among the more luminous clusters. Many clusters previously thought of as "old" and relaxed demonstrate significant variations in gas temperature, and there are correlations with luminosity, and thus mass, both in the severity and extent of the temperature variations. This high frequency of temperature variations, especially in luminous clusters at relatively low redshift ($z < 0.2$), emphasizes the need for caution in utilizing high redshift clusters to measure cosmological parameters. We find few isothermal clusters in our flux limited sample. Thus either assuming isothermality when deriving cluster masses or using the temperature as a proxy for the mass in high redshift clusters can lead to erroneous results (Markevitch et al. 2002b).

In contrast to the canonical model of little more than two decades ago, merging activity in clusters appears to be the norm rather than the exception. It is also clear from high resolution observations from *CHANDRA* and *XMM-Newton* that there is an exceptional amount of structure that awaits detailed analysis and modeling.

We thank Larry David for helpful conversations regarding the *EINSTEIN* MPC data and A.C. Edge, J. Kempner, M. Markevitch and P. Gorenstein for helpful suggestions. We acknowledge support from the Smithsonian Institute and NASA contract NAS8-39073.

REFERENCES

Abramopoulos, F. & Ku, W.H.M. 1983, ApJ, 271, 446.
Allen, S.W., Schmidt, R.W., Fabian, A.C. & Ebeling, H. 2003, MNRAS, 342, 287.
Arnaud, K., Hughes, J., Forman, W., Jones, C., Lachieze-Rey, M., Yamashita, K. & Hatsukade, I. 1992, ApJ, 390, 345.
Arnaud, K. 1993, *ASCA* Newsletter, No. 1 (NASA/GSFC).
Arnaud, M. et al. 2001a, A&A, 365, L67.
Arnaud, M., Neumann, D.M., Aghanim, N., Gastaud, R., Majerowicz, S. & Hughes, J.P. 2001b, A&A, 365, L80.
Bauer, F. & Sarazin, C.L. 2000, ApJ, 530, 222.
Bennett, C.L., et al. 2003, ApJ, (*in press*).
Blanton, E.L., Sarazin, C.L., McNamara, B.R. & Wise, M. W. 2001, ApJ, 558, L15.
Blanton, E.L., Sarazin, C.L. & McNamara, B.R. 2003, ApJ, 585, 227.
Blumenthal, G., Faber, S., Primack, J. & Rees, M. 1984, Nature, 311, 517.
Böhringer, H. et al. 2001, A&A, 265, L181.
Briel, U.G. et al. 2001, A&A, 365, L60.
Buote, D.A. & Xu, G. 1997, MNRAS, 284, 439.
Churazov, E., Gilfanov, M., Forman, W. & Jones, C. 1996, ApJ, 471, 673.
Churazov, E., Gilfanov, M., Forman, W. & Jones, C. 1999, ApJ, 520, 105.
Churazov, E., Forman, W., Jones, C. & Böhringer, H. 2003, *astroph 0301482*.
David, L.P., Arnaud, K., Forman, W. & Jones, C. 1990, ApJ, 356, 32.
David, L.P., Jones, C. & Forman, W. 1995, ApJ, 356, 32.
David, L.P., Slyz, A., Jones, C., Forman, W., Vrtilek, S.D. & Arnaud, K.A. 1993, ApJ, 412, 479 (D93).
David, L.P. et al. 2001, ApJ, 557, 546.
De Grandi, S., et al. 1999, ApJ, 514, 148.
Di Matteo, T., Allen, S.W., Fabian, A.C., Wilson, A.S. & Young, A.J. 2003, ApJ, 582, 133.
Donnelly, R.H., Markevitch, M., Forman, W., Jones, C., David, L.P., Churazov, E. & Gilfanov, M. 1998, ApJ, 500, 138.
Donnelly, R.H., Markevitch, M., Forman, W., Jones, C., Churazov, E. & Gilfanov, M. 1999, ApJ, 513, 690.
Donnelly, R.H., Forman, W., Jones, C., Quintana, H., Ramirez, A., Churazov, E. & Gilfanov, M. 2001, ApJ, 562, 254.
Dupke, R. & White, R. E., III 2003, ApJ, 583, 13.
Durret, F., Gerbal, D., Lchieze-Rey, M., Lima-Neto, G. & Sadat, R. 1994, A&A, 287, 733.
Durret, F., Lima Neto, G. B., Forman, W. & Churazov, E. 2003, A&A, 403, L29.
Ebeling, H. et al. 1998, MNRAS, 301, 881.
Edge, A.C., Stewart, G.C., Fabian, A.C. & Arnaud, K.A. 1990, 245, 559.
Edge, A.C. & Stewart, G.C. 1991a, MNRAS, 252, 414.
Edge, A.C. & Stewart, G.C. 1991b, MNRAS, 252, 428.
Edge, A.C., Stewart, G.C. & Fabian, A.C. 1992, 258, 177.
Ettori, S., Fabian, A.C., Allen, S.W. & Johnstone, R.M. 2002, MNRAS, 331, 635.
Fabricant, D., Beers, T., Geller, M., Gorenstein, P., Huchra, J.P. & Kurts, M. 1986, ApJ, 308, 530.
Gastaldello, F. & Molendi, S. 2002, ApJ, 272, 160.
Giovannini, G., Tordi, M. & Feretti, L. 2000, New Astronomy, 4, 141.
Gunn, K. & Gott, J.R.,III 1972, ApJ, 176, 1.
Heinz, S., Choi, Y., Reynolds, C.S. & Begelman, M. C. 2002, ApJ, 569, L79.
Henriksen, M.J. & Markevitch, M.L. 1996, ApJ, 466, L79.
Henriksen, M.J., Donnelly, R.H. & Davis, D.S. 2000, ApJ, 529, 692.
Henriksen, M.J. & Tittley, E.R. 2002, ApJ, 577, 701.
Hicks, A.K., Wise, M.W., Houck, J.C. & Canizares, C.R. 2002, ApJ, 580, 763.
Holzapfel, W. L., et al. 1997, ApJ, 480, 449.
Johnstone, R.M., Allen, S.W., Fabian, A.C. & Sanders, J.S. 2002, MNRAS, 336, 299.
Jones, C. & Forman, W. 1984, ApJ, 276, 38.
Jones, C. & Forman, W. 1999, ApJ, 511, 65.
Kempner, J.C. & Sarazin, C.L. 2001, ApJ, 548, 639.
Kempner, J.C., Sarazin, C.L. & Ricker, P.M. 2002, ApJ, 579, 236.
Krawczynski, H. 2002, ApJ, 569, 27.
Lewis, A.D., Stocke, J.T. & Buote, D.A. 2002, ApJ, 573, L13.
Lewis, A.D., Buote, D.A. & Stocke, J.T. 2003, ApJ, 586, 135.
Majerowicz, S., Neumann, D.M. & Reiprich, T.H. 2002, A&A, 394, 77.
Markevitch, M., Mushotzky, R., Inoue, H., Yamashita, K., Furuzawa, A. & Tawara, Y. 1996, ApJ, 456, 437.
Markevitch, M. 1996a, ApJ, 465, L1.
Markevitch, M., Sarazin, C.L. & Irwin, J.A. 1996b, ApJ, 472, L17.
Markevitch, M. & Vikhlinin, A. 1997a, ApJ, 474, 84.
Markevitch, M. & Vikhlinin, A. 1997b, ApJ, 491, 467.
Markevitch, M., Forman, W., Sarazin, C.L. & Vikhlinin, A. 1998, ApJ, 503, 77 (M98).
Markevitch, M, Sarazin, C.L. & Vikhlinin, A. 1999a, ApJ, 521, 526.
Markevitch, M. et al. 1999b, ApJ, 527, 545
Markevitch, M. et al. 2000, ApJ, 541, 542.
Markevitch, M., Vikhlinin, A. & Mazzotta, P. 2001a, ApJ, 562, L153.
Markevitch, M. & Vikhlinin, A. 2001b, ApJ, 563, 95.
Markevitch, M. 2002a, *astroph/0205333*.
Markevitch, M. et al. 2002b, ApJ, 567, L27.
Markevitch, M. et al. 2003, ApJ, 586, L19.
Mazzotta, P., Kaastra, J.S., Paerels, F.B., Ferrigno, C., Colafrancesco, S., Mewe, R. & Forman, W.R. 2002a, ApJ, 567, L37.
Mazzotta, P., Fusco-Femiano, R. & Vikhlinin, A. 2002b, ApJ, 569, L31.
McNamara, B.R. et al. 2000, ApJ, 534, 135.
McNamara, B.R. et al. 2001, ApJ, 562, L149.
Mohr, J., Fabricant, D. & Geller, M. 1993, ApJ, 413, 492.
Molendi, S. 2001, ApJ, 580, 815.
Neumann, D.M., Lumb, D.H., Pratt, G.W. & Briel, U.G. 2003, A&A, 400, 811.
Nulsen, P.E.J., David, L.P., McNamara, B.R., Jones, C., Forman, W.R. & Wise, M. 2002, ApJ, 568, 163.
Peterson, J.R. et al. 2001, A&A, 365, L104.
Reiprich, T.H. & Böhringer, H. 2002, ApJ, 567, 716.
Ricker, P.M. 1998, ApJ, 496, 670.
Sanders, J.S. & Fabian, A.C. 2002, MNRAS, 331, 273.
Sarazin, C.L., Wise, M. & Markevitch 1998, ApJ, 498, 606.
Schindler, S. & Müller, E. 1993, A&A, 272, 137.
Schmidt, R.W., Allen, S.W. & Fabian, A. C. 2001, MNRAS, 327, 1057.
Schmidt, R.W., Fabian, A.C. & Sanders, J.S. 2002, MNRAS, 337, 71.
Slezak, E., Durret, F. & Gerbal, D. 1994, AJ, 108, 1996.
Smith, D.A., Wilson, A.S., Arnaud, K.A., Terashima, Y. & Young, A.J. 2002, ApJ, 565, 195.
Sun, M., Murray, S.S., Markevitch, M. & Vikhlinin, A. 2002a, ApJ, 565, 867.
Sun, M. & Murray, S.S. 2002b, ApJ, 576, 708.
Sun, M., Jones, C., Murray, S.S., Allen, S.W., Fabian, A.C. & Edge, A.C. 2003, ApJ, 587, 619.
Takahashi, T. et al. 1995, *ASCA* Newsletter, No. 3 (NASA/GSFC).
Tamura, T. et al. 2001a, A&A, 365, L87.
Tamura, T., Bleeker, J.A.M., Kaastra, J.S., Ferrigno, C. & Molendi, S. 2001b, A&A, 379, 107.
Vikhlinin, A., Markevitch, M. & Murray, S.S. 2001, ApJ, 551, 160.
Watanabe, M., Yamashita, K., Furuzawa, A., Kunieda, H. & Tawara, Y. 2001, PASJ, 53, 605.
White, D. & Fabian, A. 1995, MNRAS, 273, 72.
White, S., Briel, U. & Henry, J.P. 1993, MNRAS, 261, 8.
Xue, S. & Wu, X. 2002, ApJ, 576, 152.
Yamasaki, N.Y., Ohashi, T. & Furusho, T. 2002, ApJ, 578, 833.

Table 1. Observational Data

Cluster	α^{a}	δ^{a}	z	Seq. No.	On Time	$n_H{}^{b}$	kT^{c}	F^{d}	L^{e}	Struc.	Index
A85	0:41:45	-9:19.6	0.0555	81024000	25111	3.58	$6.7^{+0.1}_{-0.2}$	6.22	3.59	1S	20
				81024010	10282						
A119	0:56:15	-1:15.2	0.0442	83045000	33951	3.10	$5.7^{+0.2}_{-0.2}$	2.75	1.03	1L	42
A262	1:52:50	36:08.8	0.0163	81031000	15861	5.36	$2.1^{+0.1}_{-0.1}$	2.24	0.12	–	59
AWM7	2:54:26	41:34.8	0.0172	80036000	10374	9.21	$3.8^{+0.2}_{-0.1}$	8.58	0.52	–	54
A399	2:57:48	13:03.2	0.0724	82008000	27942	10.60	$7.7^{+0.4}_{-0.4}$	3.42	3.23	1L	22
A401	2:58:57	13:34.3	0.0737	82010000	31264	10.30	$9.2^{+0.3}_{-0.4}$	5.73	5.59	1L	11
				82009000	32374						
A3112	3:17:58	-44:14.2	0.0750	81003000	36000	2.55	$4.6^{+0.2}_{-0.1}$	1.94	1.95	2L	31
A426/Perseus	3:19:49	41:30.9	0.0179	80007000	12202	15.70	$5.1^{+0.1}_{-0.1}$	75.4	4.94	2L	13
				80008000	19924						
				83051000	12238						
				83053000	13500						
2A0335+96	3:38:39	9:58.3	0.0349	82029000	17262	18.00	$3.1^{+0.1}_{-0.1}$	4.65	1.11	2S	41
				82040000	36320						
A3158	3:42:40	-53:37.8	0.0597	84020000	30101	1.06	$5.6^{+0.2}_{-0.2}$	2.47	1.63	2S	35
A478	4:13:26	10:27.9	0.0881	81015000	32053	15.30	$6.4^{+0.3}_{-0.3}$	5.70	7.68	2S	8
A3266	4:31:23	-61:25.0	0.0589	83023000	32299	1.48	$9.3^{+0.4}_{-0.4}$	5.48	3.53	2L	21
A496	4:33:39	-13:15.4	0.0329	80003000	32636	4.56	$4.1^{+0.1}_{-0.1}$	5.30	1.13	2S	39
3C129.1	4:49:59	45:02.2	0.0223	86050000	38089	73.30	$5.9^{+0.1}_{-0.1}$	8.46	0.85	1S	45
A3391	6:26:22	-53:41.3	0.0514	72019000	16945	5.42	$5.7^{+0.4}_{-0.3}$	1.78	0.89	1S	44
A3395	6:27:14	-54:28.5	0.0506	82033000	31065	5.42	$4.7^{+0.2}_{-0.2}$	1.93	0.94	1L	43
A576	7:21:31	55:46.0	0.0389	84001000	41548	5.69	$3.8^{+0.2}_{-0.1}$	1.97	0.58	–	53
PKS0745-19	7:47:31	-19:17.6	0.1028	81016000	35834	43.80	$6.4^{+0.1}_{-0.2}$	5.71	10.14	1L	3
A644	8:17:23	-7:31.4	0.0704	83022000	54396	6.76	$7.8^{+0.3}_{-0.3}$	4.13	3.70	1S	18
A754	9:09:04	-9:39.9	0.0542	82057000	21598	4.21	$11.8^{+0.8}_{-0.5}$	7.26	4.00	3L	15
Hydra A	9:18:06	-12:05.9	0.0538	80015000	18714	4.93	$3.7^{+0.2}_{-0.1}$	3.00	1.63	–	36
A1060	10:36:51	-27:31.6	0.0126	80004000	29701	4.93	$3.1^{+0.1}_{-0.1}$	4.88	0.16	–	58
A1367	11:44:44	19:43.0	0.0220	81029000	10624	2.19	$3.7^{+0.1}_{-0.1}$	3.35	0.33	2L	56
				81029010	8030						
				81030000	7292						
				81030010	9654						
Z5029	12:17:41	3:39.5	0.0750	—	—	1.73	6.3^{e}	1.79^{R}	1.80		33
Virgo*(core)	12:30:48	12:23.8	0.0036	60033000	11998	2.64	$2.4^{+0.1}_{-0.1}$	30.0	0.08	–	60
A3526/Centaurus	12:48:54	-41:18.3	0.0114	80032000	14710	8.07	$3.5^{+0.1}_{-0.1}$	10.3	0.28	1S	57
				80033000	11150						
				80034000	12368						
				83026000	57230						
A1644	12:57:15	-17:21.2	0.0473	—	—	4.82	$4.7^{+0.9}_{-0.7}$	2.71	1.16		38
A3532	12:57:20	-30:22.1	0.0554	86014000	23573	5.96	$4.3^{+0.2}_{-0.2}$	1.95	1.12	–	40
				86016000	24781						
A1650	12:58:41	-1:45.5	0.0845	84021000	43394	1.54	$5.8^{+0.2}_{-0.2}$	2.18	2.73	1S	25
A1651	12:59:23	-4:11.2	0.0844	82036000	35025	1.71	$6.3^{+0.4}_{-0.3}$	3.67	4.58	1L	14
A1656/Coma	12:59:44	27:56.3	0.0231	80016000	7462	0.89	$9.0^{+0.3}_{-0.4}$	25.1	2.70	1L	26
A1689	13:11:34	-1:21.9	0.1832	80005000	29324	1.82	$9.4^{+0.7}_{-0.4}$	1.72	8.13	1L	5
A1736	13:26:59	-27:09.5	0.0458	83061000	16378	5.36	$3.8^{+0.2}_{-0.1}$	1.74	0.70	1L	49
A3558	13:27:58	-31:30.2	0.0480	82046000	13967	3.84	$5.8^{+0.3}_{-0.2}$	4.21	1.85	–	32
A3562	13:33:39	-31:40.5	0.0490	84041000	15365	3.91	$5.0^{+0.3}_{-0.3}$	3.62	1.65	–	34
A3571	13:47:30	-32:51.7	0.0391	82047000	23886	3.31	$8.3^{+0.3}_{-0.3}$	12.3	3.66	1L	19
A1795	13:48:49	26:36.5	0.0631	80006000	31809	1.18	$6.1^{+0.2}_{-0.1}$	5.19	3.80	1S	17
A1835	14:01:02	2:52.7	0.2532	82052000	14932	2.40	$7.7^{+0.5}_{-0.5}$	1.75^{R}	13.64	1L	1
				82052010	13614						
A2029	15:10:59	5:44.8	0.0773	81023000	30409	3.03	$7.1^{+0.3}_{-0.2}$	7.52	8.00	2S	6
A2052	15:16:46	7:00.0	0.0350	85061000	35919	2.78	$3.0^{+0.1}_{-0.1}$	2.48	0.60	–	52
MKW3s	15:21:50	7:42.4	0.0450	80011000	24806	3.01	$3.4^{+0.2}_{-0.1}$	1.71	0.66	–	50
A2065	15:22:27	27:42.8	0.0726	84054000	23430	2.87	$5.8^{+0.2}_{-0.2}$	2.75	2.61	1L	28
				84054010	20382						
A2063	15:23:07	8:36.8	0.0353	81002000	20000	2.92	$2.6^{+0.2}_{-0.1}$	2.46	0.60	–	51
A2142	15:58:23	27:14.3	0.0909	81004000	13878	4.05	$8.7^{+0.6}_{-0.6}$	6.77	9.65	1S	4
A2147	16:02:19	15:59.0	0.0350	83074000	30613	3.46	$4.5^{+0.1}_{-0.2}$	2.96	0.71	–	48
A3627	16:14:08	-60:52.2	0.0157	84005000	35394	20.70	$5.4^{+0.1}_{-0.1}$	15.7^{R}	0.80	2L	47
				84005010	24269						
A2163	16:15:45	-6:08.2	0.2030	80024000	26628	12.30	$11.5^{+0.9}_{-0.8}$	2.33	12.97	2L	2
A2199	16:28:38	39:33.3	0.0299	80023000	27433	0.87	$4.4^{+0.1}_{-0.1}$	6.94	1.23	–	37

Table 1. Observational Data— *Continued*

Cluster	α[a]	δ[a]	z	Seq. No.	On Time	n_H[b]	kT[c]	F[d]	L[e]	Struc.	Index
A2204	16:32:46	5:34.6	0.1523	82045000	13728	5.94	$7.1^{+0.2}_{-0.3}$	2.20	7.68	1L	7
				82045010	15294						
Tri. Aust.	16:38:16	-64:21.2	0.0510	83060000	11554	12.30	$10.7^{+0.5}_{-0.5}$	11.0	5.41	1L	12
				83060010	6762						
A2244	17:02:39	34:04.0	0.0968	86073000	29111	2.07	$5.6^{+0.2}_{-0.2}$	1.68	2.68	3S	27
A2256	17:04:01	78:37.9	0.0581	10004020	8764	4.11	$7.4^{+0.2}_{-0.1}$	5.05	3.17	2L	23
				10004030	23652						
				80002000	33908						
Ophiuchus	17:12:24	-23:21.0	0.0280	80027000	7262	21.60	$12.1^{+0.6}_{-0.4}$	43.7	6.84	3L	10
A2255	17:12:50	64:03.7	0.0806	84012000	39173	2.55	$6.3^{+0.3}_{-0.2}$	1.71	1.96	1L	30
				84012010	31333						
A2319	19:21:09	43:59.3	0.0557	80041000	13458	7.02	$9.9^{+0.4}_{-0.4}$	12.1	7.02	3L	9
				80041010	11662						
Cygnus A	19:59:24	40:45.6	0.0569	70003000	22006	31.30	$6.0^{+0.1}_{-0.4}$	4.78	2.78	2L	24
				70003010	28660						
A3667	20:12:25	-56:49.6	0.0556	83054000	17920	4.77	$7.1^{+0.3}_{-0.3}$	6.68	3.86	1L	16
A2597	23:25:17	-12:07.6	0.0852	83062000	40230	2.46	$3.7^{+0.1}_{-0.1}$	1.90	2.41	–	29
A4038	23:47:41	-28:08.7	0.0300	83004000	45581	1.55	$3.1^{+0.1}_{-0.1}$	2.55	0.46	–	55
A4059	23:57:03	-34:45.1	0.0475	82030000	33385	1.10	$4.2^{+0.2}_{-0.1}$	1.88	0.81	–	46

[a] Coordinates are J2000.

[b] $\times 10^{20}$ cm^{-2}. Weighted Galactic n_H within 0.5° radius cone from the FTOOL *nh*.

[c] keV. Single component Raymond-Smith model of composite spectrum within a radial distance of 1 Mpc or 20′, whichever was smaller. The temperature for A1644 is the result from D93 using MPC data; for Z5029 the result is an estimate based on the *ROSAT* PSPC flux and the L_X-kT relation (Ebeling et al. 1998).

[d] $\times 10^{-11}$ ergs sec^{-1} cm^{-2}. Unabsorbed flux within a radial distance of 22.5′ from the *EINSTEIN* MPC (D93). For clusters noted with a ^{R} the estimates are from the *ROSAT* PSPC and PIMMS.

[e] $\times 10^{44}$ ergs sec^{-1}. Luminosities found using the tabulated fluxes and distances assuming a *WMAP* cosmology.

This figure "figure2d.gif" is available in "gif" format from:

http://arXiv.org/ps/astro-ph/0310145v2